Social contact and other-race face processing in the human brain

Pamela M. Walker, Laetitia Silvert, Miles Hewstone, and Anna C. Nobre

Department of Experimental Psychology, University of Oxford, Oxford, UK

The present study investigated the influence social factors upon the neural processing of faces of other races using event-related potentials. A multi-tiered approach was used to identify face-specific stages of processing, to test for effects of race-of-face upon processing at these stages and to evaluate the impact of social contact and individuating experience upon these effects. The results showed that race-of-face has significant effects upon face processing, starting from early perceptual stages of structural encoding, and that social factors may play an important role in mediating these effects.

The complexity of human social behavior reflects the interactions of numerous social factors with underlying neural systems that are integral for the perception of social signals (Adolphs, 2001). In particular, social experience has been demonstrated to mold the way in which individuals recognize familiar faces (Carroo, 1987), as well as own-race *vs* other-race faces (Walker and Hewstone, 2006a). Behavioral research over the past few decades has suggested that increased experience with faces of one's own-race *vs* other-races can shape the initial way in which faces are encoded (O'Toole *et al.*, 1991; Walker and Tanaka, 2003).

Face perception is a key example of a well-tuned perceptual system. Individuals are able to recognize and remember countless numbers of faces, subsequently facilitating interpersonal communication. Much attention has been paid to the neural basis of face perception. Intracranial recordings of field potentials from the cortical surface of neurological patients and non-invasive hemodynamic imaging studies with healthy volunteers have suggested the existence of a visual area specialized for processing faces located in the middle section of the fusiform gyrus. Face stimuli have consistently elicited significantly more activation in this region than other objects or scrambled face stimuli (Sergent *et al.*, 1992; Allison *et al.*, 1994a, b; Puce *et al.*, 1995, 1996; Kanwisher *et al.*, 1997). Intracranial recordings from this region show face-related components peaking around 200 ms, sensitive to the configural arrangement of facial features, face orientation and direction of gaze (McCarthy *et al.*, 1999), but typically unaffected by top-down factors such as familiarity, repetition or semantic priming (Puce *et al.*, 1999). These brain-imaging findings complement the neuropsychological observations of

prosopagnosia after lesions to the occipitotemporal region (Bodamer, 1947; Damasio *et al.*, 1982).

Additional brain areas may contribute specialized perceptual functions during face recognition. Functional Magnetic Resonance Imaging (fMRI) and intracranial recordings have shown face-related responses in right posterior lateral temporal areas around the superior temporal sulcus (STS: Puce *et al.*, 1996; Allison *et al.*, 1999), where activity is modulated by mouth and gaze movement (Puce *et al.*, 1998, 2003; Haxby *et al.*, 2000; Pelphrey *et al.*, 2003). Intracranial recordings show that activity in this region occurs around the same time as early face-related activity in the fusiform gyrus (peaking around 200 ms) (Allison *et al.*, 1999). The dynamic perceptual functions in this area have been proposed to contribute to extracting socially relevant variables, such as intention (Frith and Frith, 1999; Allison *et al.*, 2000) trustworthiness (Winston *et al.*, 2002) or theory-of-mind judgments (Fletcher *et al.*, 1995; Gallagher *et al.*, 2000). Intracranial recordings have also identified face-specific components in the anterior medial temporal cortex (Allison *et al.*, 1994b, 1999), which are modulated by top-down factors such as familiarity and semantic priming (Nobre and McCarthy, 1994; Puce *et al.*, 1999). It is likely that this area is not conspicuous in hemodynamic studies of face perception, as it is notoriously difficult to obtain a reliable signal from this region due to magnetic distortions and drop out.

Event-related potentials (ERPs) recorded from the scalp have also been used to study face perception. Faces elicit characteristic components during perceptual analysis, known as the N170 and the vertex positive potential, or VPP (Bentin *et al.*, 1996; Jeffreys, 1989). The N170 is a negative deflection distributed over lateral posterior electrodes and larger over the right hemisphere. The VPP is a concomitant positive deflection over midline parietal electrodes. These two components co-vary in functional and temporal properties across recording parameters, and may represent two aspects

of the same underlying brain process (Joyce and Rossion, 2005). They have been linked to structural encoding (Eimer, 1998, 2000), and may reflect activity around the fusiform gyrus and STS (Itier and Taylor, 2004a, b; Puce *et al.*, 2003; Rossion *et al.*, 2003).

Indeed, modulations of the N170 component are consistent with face-specific behavioral effects. Inversion of face stimuli impairs behavioral measures of face recognition or matching, and leads to significant delays and sometimes amplification of the N170 (Rossion *et al.*, 1999, 2000). The modulations of the N170 may reflect disruption of structural encoding when face stimuli are not in their canonical orientation (George *et al.*, 1996). Likewise, latency shifts have been reported for faces without eyes compared to intact faces (Eimer, 1998), and when participants process face components analytically rather than holistically (Jemel *et al.*, 1999).

Knowledge of face processing in the brain can be used to investigate the neural basis of a pervasive social and cognitive phenomenon, known as the own-race effect: individuals demonstrate greater difficulty in recognizing other-race faces than own-race faces. This social-cognitive phenomenon has been noted as an impediment in interracial social communication and eye-witness identification (Sporer, 2001; Wright *et al.*, 2003). The neural circuitry involved in the categorization by race-of-face has been examined by fMRI studies (for a review see Eberhardt, 2005). Activation in the middle fusiform gyrus is modulated by race, being larger for own-race faces (Golby *et al.*, 2001; Golarai *et al.*, 2004); and activation in the dorsolateral prefrontal cortex, involved in executive control, is modulated by racial bias in response to other-race faces (Richeson *et al.*, 2003). Activation in the amygdala, a limbic structure implicated in processing emotional and motivationally salient stimuli, is also modulated by race-of-face (Cunningham *et al.*, 2003; Hart, *et al.*, 2000; Lieberman *et al.*, 2005), habituating faster to own-race *vs* other-race faces (Hart *et al.*, 2000). Greater activation in the amygdala has been observed to other-race faces during social-categorization tasks (Wheeler and Fiske, 2005) or when presented subliminally (Cunningham *et al.*, 2004). Moreover, amygdala activation to other-race faces correlates with measures of implicit social bias (Phelps *et al.*, 2000) supporting the involvement of the amygdala in explicit and implicit race evaluation.

Whereas, fMRI data indicate that the activation of different regions of the face/emotion processing circuit can be modulated by racial factors, the functional significance of these modulations remains unclear, partly due to the poor temporal resolution of the technique. It is important to determine if racial factors can influence perceptual stages of face processing, suggesting automatic and rapid consequences of motivational or limbic factors coded by limbic structures or very rapid perceptual out-group categorization (Levin, 2000; Caldara *et al.*, 2003); or if racial factors only affect neural activity at late stages, as a product of cognitive or emotional valuation.

Evidence about the timecourse of the effects of racial factors on face processing is crucial to the understanding of the own-race effect at a neural level. ERP studies have the ability to clarify whether social factors such as race can influence early stages of perceptual analysis (e.g. structural encoding reflected by the N170) or whether they bias later, more controlled postperceptual aspects of face recognition. To date, however, electrophysiological evidence has been inconclusive (James *et al.*, 2001; Caldara *et al.*, 2003, 2004; Ito and Urland, 2003, 2005; Ito *et al.*, 2004). Certain researchers have reported no modulation of the N170 and have suggested that race-of-face processing does not affect face structural encoding (James *et al.*, 2001; Caldara *et al.*, 2003, 2004; Ito *et al.*, 2004). Ito and colleagues (2003, 2004, 2005), however, have found own-race faces to elicit a larger N170 than other-race faces, with greater effects during social categorization tasks than during non-social categorization tasks. Their findings demonstrate that the context in which we look at a face may dictate the priority of initial information extraction during structural encoding.

The 'contact hypothesis' (Allport, 1954; Brown and Hewstone, 2005) offers a potential explanation for the discrepant effects of race upon early stages of face processing. It proposes that conditions fostering intergroup contact, including contact between ethnic and racial groups, can ultimately reduce prejudice and improve intergroup relations (Pettigrew and Tropp, 2006). One interesting possibility is that contact may influence processing of other-race stimuli, such as faces, from early perceptual stages. Previous research by Walker and Hewstone (2006a; in press) has demonstrated the link between social exposure and an own-race effect in perceptual expertise. Hence, individuals with more interracial experience are predicted to show a diminished own-race effect, as these high-contact individuals are likely to encode other-race faces in a similar manner to own-race faces (Walker and Tanaka, 2003). Conversely, individuals with less other-race contact may allocate their perceptual resources to face categorization (Levin, 2000), making other-race face differentiation more difficult.

The current study revisited the influence of race-of-face on perceptual and later stages of neural processing of faces, and specifically tested the effects of social contact in mediating the effects. ERPs were used as a tool to investigate components sensitive to differences in processing own-race *vs* other-race faces in White participants. The experiment used a three-tiered strategy. First, face-related neural activity (including the N170 component) was identified by comparing processing of upright White faces to control stimuli with the same overall size, shape and luminance, but without any facial features; as well as to the processing of face stimuli rotated by 180°. Second, the effect of stimulus race upon face-related components was tested. Finally, the relationship between ERP race effects and measures of other-race social contact was investigated.

METHODS

Participants

Thirteen healthy right-handed (Oldfield, 1971) White female[1] students at a British university (age range 18–24 years) took part in the experiment. The experimental methods were non-invasive and had approval from the departmental ethics committee.

Stimuli and materials

Participants completed two self-report questionnaires regarding (i) quantity of social-contact, and (ii) individuating experience. All items used a 5-point scale, anchored by 1(low contact) and 5 (high contact). Questionnaires were completed either before or after the electroencephalogram (EEG) recording, counterbalanced across participants.

The social-contact scale measured participant's quantity of other-race contact and included five items modeled after Voci and Hewstone (2003); Cronbach's $\alpha = 0.87$. Item (i) asked, 'How many Black people do you know very well?' with the answer choices: *Up to 2, Up to 5, Up to 8, Up to 12* and *More than 12*. Items 2–8 used the following scale: *strongly agree, sort of agree, not sure, sort of disagree, strongly disagree* and were worded as: (ii) 'I often talk to Black people in college', (iii) 'I often see Black people outside of college', (iv) 'I often hang out with Black people' and (v) 'I often see Black people at social events I attend'.

The 10-item individuating experience scale ($\alpha = 0.94$) investigated the participant's quality of other-race contact and used the following response alternatives: *Never, rarely, once in a while, sometimes, frequently*. The first two items were taken from quality of contact scales from Turner *et al.* (in press) and Paolini and Hewstone (2004, 2007) and were worded as follows (i) 'How often do you spend time with Black friends/friend at their place?', and (ii) 'How often do you have Black friends round to your place?'.We sought to improve on these earlier measures by developing the items 3–10, specifically asking about contact that was more linked to individuation via prosocial behavior, empathy, cooperation and self-disclosure: (iii) 'How often have you helped someone Black with a problem they had in class?', (iv) 'How often have you asked for/received help from someone Black when you had a problem in class?', (v) 'How often have you given a Black person advice on a personal problem?', (vi) 'How often have you received advice from a Black person when you are having a personal problem?', (vii) 'How often have you comforted a Black person when they were upset/ sad?', (viii) 'How often have you been comforted by a Black person when you were upset/sad?', (ix) 'How often have you worked with Black classmates on projects?' and (x) 'How often have you had a Black person on your team during sports or your group during other activities?'.
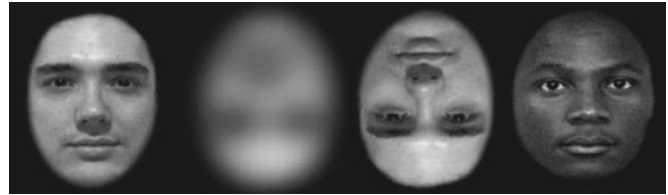

Fig. 1 Face stimuli from left to right: White upright; White Blur; White inverted; Black upright.

Overall, participants reported slightly below mid-point social-contact, $M = 2.55$, s.d. $= 1.00$, and average individuating experience, $M = 2.94$, s.d. $= 0.73$. No significant inter-correlation was found between these two measures.

Participants viewed black-and-white photographs of face stimuli of five White and five Black males with neutral expression from a frontal viewpoint. From these face stimuli, further experimental stimuli were generated. White and Black face stimuli were blurred using a Gaussian transformation and rotated 180°, becoming no longer identifiable as faces (referred to as 'blurs'). White and Black face stimuli were rotated by 180° (referred to as 'inverted', Figure 1).

In total, participants viewed 30 distinct face stimuli (five upright White, five upright Black, five White blurs, five Black blurs, five inverted White and five inverted Black[2]). Stimuli were intermixed across trials and were repeated 12 times in a constrained randomized order, which avoided immediate repetition of stimuli from the same category. Six additional 'target' stimuli per category (10% of all trials) appeared directly after an identical stimulus. In total, there were 396 trials.

Each trial consisted of a fixation point presented in the centre of the screen for 1000 ms followed by a face or transformed face stimulus for 500 ms. Trials were separated by an interval ranging between 1000 and 2500 ms. Participants responded when they detected a stimulus that repeated over immediately successive trials (targets), by pressing the right-mouse button.

Procedure

Participants sat in a dimly lit and electrically shielded room, facing a computer monitor ∼100 cm away. They were given task instructions and a block of 12 practice trials prior to task performance. Participants were asked to minimize blinking and to maintain visual fixation in the centre of the screen during task performance.

ERP recording

The EEG was recorded continuously from 34 scalp sites using Ag/AgCl electrodes mounted on an elastic cap (Easy-Cap, FMS, Germany), positioned according to the 10–20 International System (AEEGS, 1991). The montage included six midline sites (FZ, FCZ, CZ, CPZ, PZ and OZ); 14 sites

---

1 Female participants and male face stimuli were included in the present experiment to control for an own-gender bias in face processing (Wright and Sladden, 2003) and own- *vs* other-race face recognition (Slone, *et al.*, 2000).

2 The inverted Black faces were irrelevant to the experimental analyses; however, these faces were included so that participants were presented with an equal number of White and Black face stimuli.

over each hemisphere (FP1/FP2, F3/F4, F7/F8, FC3/FC4, FT7/FT8, C3/C4, T7/T8, CP3/CP4, TP7/TP8, P3/P4, P7/P8, PO3/PO4, PO7/PO8 and O1/O2) and both mastoids. Two additional electrodes were used as reference (nose) and ground (AFZ) sites. Electrodes placed laterally to each eye and below the right eye were used to derive bipolar horizontal and vertical electrooculogram signals. Data were digitized at a sampling rate of 500 Hz, using a 200 Hz low-pass filter and no high-pass filter (DC).

Analysis concentrated on non-target trials, in order to avoid any contribution from components related to response-related processes. The EEG was segmented offline into epochs starting 200 ms before and ending 600 ms after stimulus onset. Epochs were eliminated if they contained excessive noise or drift (greater than $\pm 100 \mu V$) at any electrode, or eye blinks in the EOG electrodes (greater than $\pm 50 \mu V$). Saccades or breaks in central fixation were monitored with an infrared eye-tracker (iView, SMI); trials with breaks in fixation were removed from analysis.

ERP analysis

Topographical ERP analyses. To identify significant differences in the nature of neural processing engaged by face stimuli, ERPs elicited by upright White faces and blur stimuli were summarized by a limited number of scalp potential fields referred to as 'segmentation maps' using Cartool software (Brunet, Functional Brain Mapping Laboratory, Geneva, Switzerland). These segmentation maps represent periods of stable electric field patterns and reflect dissociable functional states of the brain (Michel *et al.*, 1992; Pasqual-Marqui *et al.*, 1995). By comparing the maps and their durations across experimental conditions, it is possible to determine whether functional states differ in nature or timecourse between conditions (Khateb *et al.*, 1999).

For the segmentation analysis, ERPs for each subject and condition were recalculated against the average reference and normalized to their global field power (GFP, Lehman and Skrandies, 1980) before group averaging.[3] The most dominant scalp topographies appearing in the group averaged ERP from each condition over time were identified. This analysis was completed from 0 to 430 ms after stimulus onset with the constraint that a given scalp topography lasted at least 6 ms. The optimal number of maps that best explained the entire data set was defined by a cross-validation criterion (Pascual-Marqui *et al.*, 1995), resulting in a sequence of non-overlapping scalp-topography configurations for each condition (Figure 2). Finally, a fitting procedure was conducted by evaluating the significance of each map for a given condition. The scalp topography data for individual subjects in each condition and time-point were compared to the segmentation maps and subsequently labeled according to the one with which they were best
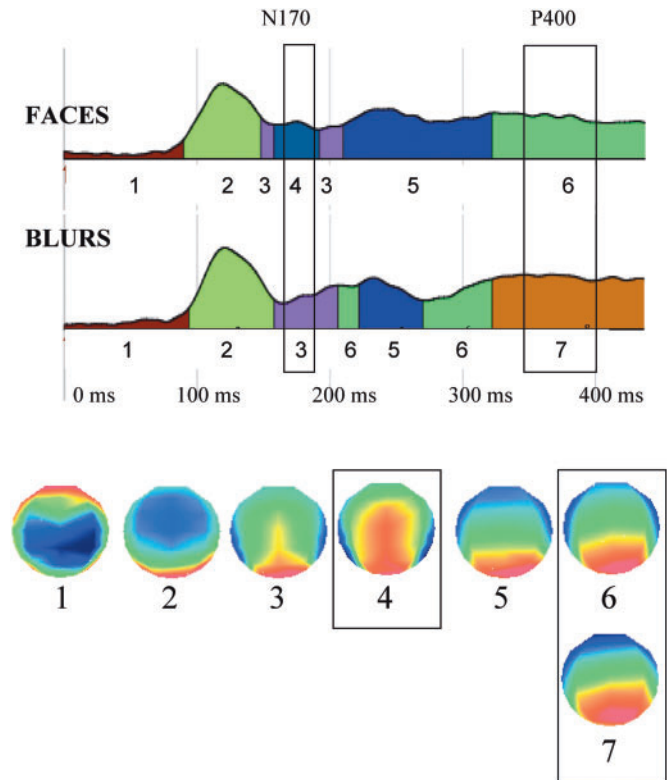
---

[3] Calculated as the square root of the mean of the squared value recorded at each electrode (*vs* the average reference) and is equivalent to the spatial standard deviation of the scalp electric field.

Fig. 2 White Faces *vs* White Blurs: Segmentation maps and scalp topographies. (*Note.* The segmentation map numbers correspond to the scalp topography numbers.)

correlated (Pegna *et al.*, 1997). This comparison allows not only the verification of the presence of particular maps in each condition in each set of subject data, but also serves to determine the total amount of time. A given topography was observed for the experimental conditions across subjects (Brandeis *et al.*, 1992). Repeated-measures analyses of variance (ANOVA) were then performed on these latter values.

Morphological ERP analysis. Face-related neural activity was also identified by comparing waveforms of the upright White faces to blur stimuli (Figure 3). Waveforms of the upright faces were characterized by early visual responses over lateral posterior sites (N170), a later negative peak over frontocentral sites (N210) and a late positive frontal peak (P400). Mean amplitudes and latencies of these components, as well as of the early visual (P120) component, were compared between experimental conditions using repeated-measures ANOVAs.

For each experimental condition (Black upright faces, White inverted faces, White face blurs) and each component, mean amplitudes were measured over symmetrical electrode clusters where the component was largest for upright White faces, using the time period around the peak latency in the group data. The visual P120 component was measured between 100 and 140 ms at electrodes PO3/PO4 and O1/O2; N170 at P7/8 and PO7/8 between 160 and 180 ms; N210 at CP3/CPZ/CP4 and P3/PZ/P4 between 200 and 220 ms and
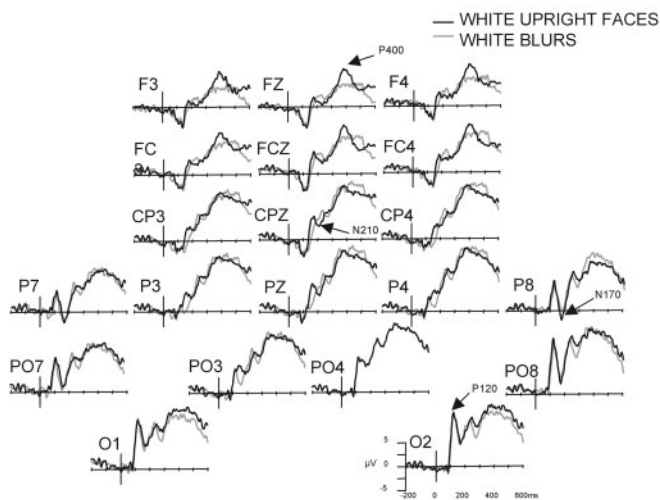
Fig. 3 ERP grand average waveforms of 20 of the 34 electrodes recorded. White upright faces are overlaid with White face blurs for comparison.

P400 at F3/FZ/F4 and FC3/FCZ/FC4 between 360 and 420 ms. Measures of peak latency were taken at the single electrode where the component was maximal in the group data for White upright faces, using a more extensive time window to allow for individual variability. The P120 peak latency was measured at O2 between 90 and 150 ms; N170 at P8 between 140 and 200 ms; N210 at CPZ between 180 and 300 ms and P400 at FZ between 300 and 500 ms (Figure 4).

Repeated-measures ANOVAs assessed the effects of stimulus type on the amplitude and latency of each component (P120, N170, N210 and P400) with electrode location (e.g. CP and P for the N210) and hemisphere (e.g. right, midline and left for the N210) as supplementary factors for amplitude measures. First, upright White face stimuli were compared with White face blurs, second, White upright faces were compared with White inverted faces and third, effects of Race of Face were investigated (White upright face vs Black upright face stimuli.). Supplementary analyses comparing White vs Black face blurs were conducted on the component reflecting face structural encoding (N170) demonstrating a significant race-of-face effect, in order to determine whether the effect was race or color related. The Greenhouse-Geiser epsilon correction for non-sphericity was applied where appropriate (Jennings and Wood, 1976). Only corrected probability values and degrees of freedom are reported. For all components, effects of interest only included main effects or interactions involving stimulus type.

RESULTS
Behavioral results
Overall, participants were highly accurate at detecting immediate repetitions of the different stimulus types

(M = 92%, s.d. = 11% across conditions), indicating that they remained alert and attentive throughout the task. A 2(Race-of-face: White vs Black) by 3 (stimulus type: blur vs upright vs inverted) repeated-measures ANOVA was conducted on response accuracy scores to target face stimuli, to test for effects of Race-of-face. No significant effects were observed, $P > 0.05$.

ERP results
Upright White faces vs *blurs.* The analysis of ERPs elicited by upright White faces and blurs revealed the traditional face-specific N170 component over lateral posterior sites and identified two further face-related components: a negative peak over central-parietal sites around 210 ms, and a late positive frontal peak around 400 ms.

Topographical analysis. The topographical segmentation analysis supported the occurrence of face-specific components between 156 and 202 ms and 322 and 430 ms. The segmentation analysis for upright White face vs blur stimuli yielded a total of seven maps (Figure 2). An early difference between conditions appeared from 158 to 192 ms (map 4 for faces vs map 3 for blurs), around the face-specific N170 component (Bentin et al., 1996). A later difference occurred between 322 and 430 ms (map 6 for faces vs map 8 for blurs). Repeated-measures ANOVAs compared the total amount of time for each topography in a given condition across subjects. The factors were experimental condition (face/blur) and segmentation map (4/3 for 156–202 ms and 6/7 for 322–430 ms). In the 158–192 ms time period, a significant interaction of condition by map, $F(1, 12) = 4.95$, $P < 0.05$, demonstrated that map 4 occurred significantly more often in the face vs blur condition. In the second time window (322–430 ms), a significant interaction of condition by map, $F(1, 12) = 31.62$, $P < 0.001$, demonstrated that map 6 occurred more frequently for the face vs blur condition.

Morphological analysis. Comparisons of the mean amplitudes of the ERP components elicited by White faces and blurs showed multiple components sensitive to stimulus type. The first of these was the N170. Faces elicited a significantly larger N170 component over right lateral posterior electrodes, as revealed by an interaction between stimulus type and hemisphere, $F(1, 12) = 6.50$, $P < 0.05$. Following the N170, a brief negative component over the centro-parietal scalp region peaking around 210 ms (N210) was observed for face but not blur stimuli. Though this component was not brought to the fore by the topographical analysis, analysis of mean amplitudes during this time period showed a main effect of stimulus, whereby the N210 was more negative for faces than blurs, $F(1, 12) = 4.81$, $P < 0.05$. Finally, an interaction of face-by-electrode modulated the mean amplitude of the P400; the component was larger for face vs blur stimuli at frontal sites, $F(1, 12) = 7.05$, $P < 0.01$. No significant latency effects were observed.
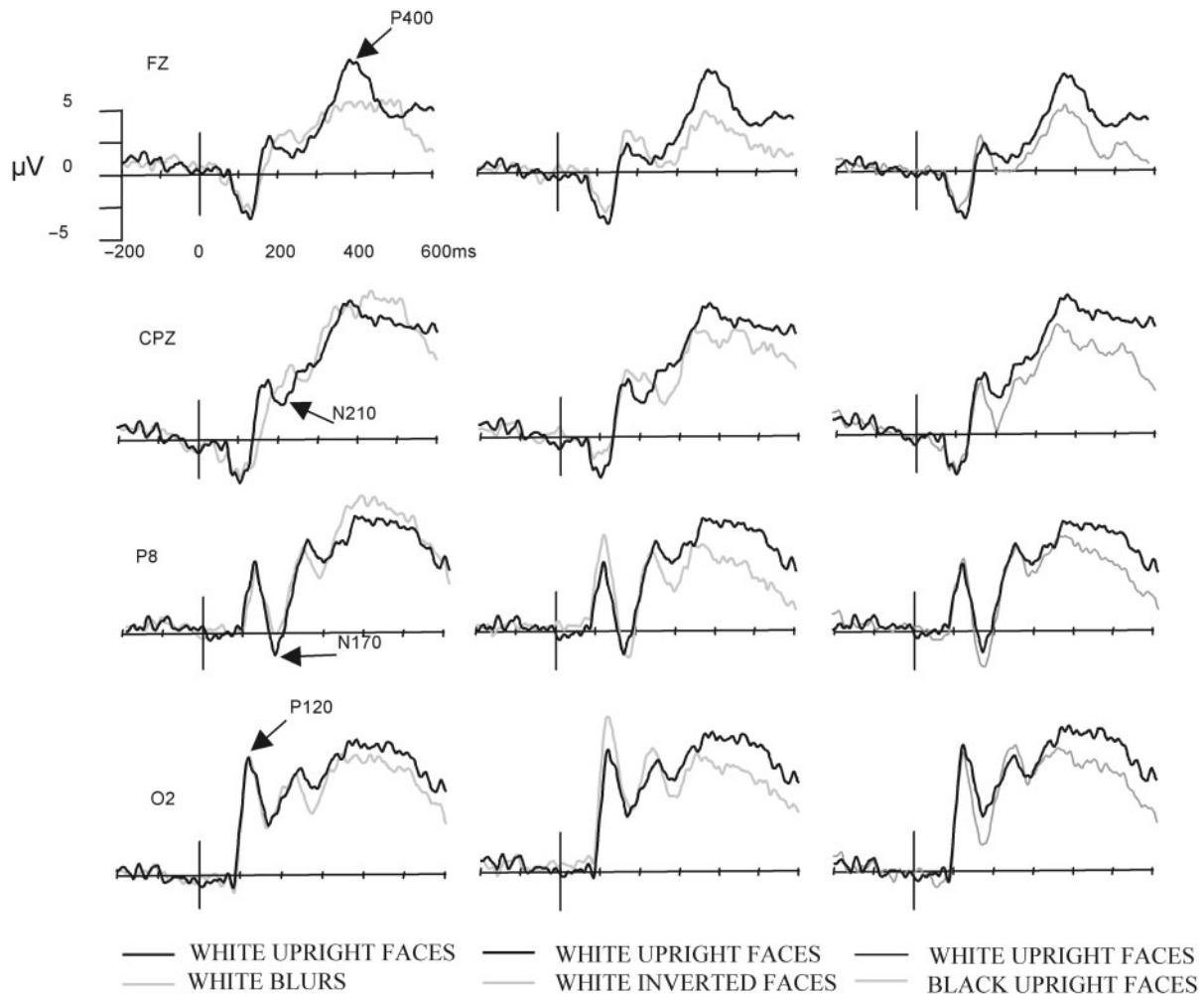
Fig. 4 ERP grand average waveforms of the four components: P400 (at FZ), N210 (at CPZ), N170 (at PO8), and P120 (at O2).

Upright vs *inverted White faces.* Face orientation was found to modulate the latency and/or amplitude of multiple components. Both the amplitude and the latency of the early visual P120 component were affected. Amplitude modulation involved an interaction between orientation and electrode site, such that the component was largest for inverted faces at O1/O2, $F(1, 12) = 7.05$, $P < 0.05$. The peak latency of the P120 component was earlier for inverted faces than for upright faces, $F(1, 12) = 8.23$, $P < 0.05$. Face orientation modulated the latency, $F(1, 12) = 6.16$, $P < 0.05$, but not the amplitude of the face-related N170 component, with a delayed peak for inverted faces. Orientation modulated the mean amplitude of the N210, interacting with hemisphere and electrode site, $F(1.94, 23.22) = 4.15$, $P < 0.05$, maximal for upright faces at P4. The N210 was also delayed for inverted *vs* upright faces, $F(1, 12) = 16.02$, $P < 0.005$. Finally, face orientation modulated the mean amplitude of the P400, $F(1, 12) = 8.12$, $P < 0.05$, with inverted faces showing a diminished amplitude.

Effects of race-of-face. Face-related processing was modulated by race, starting from the structural encoding phase. The mean amplitude of the N170 was modulated by a main effect of race, $F(1, 12) = 8.51$, $P < 0.05$, such that Black faces elicited a larger N170 than White faces. ERPs to Black *vs* White face blurs were subsequently analyzed during the same timeframe, however, no main effect of color was observed, substantiating the main effect of race during the stage of face structural encoding. A main effect of race was observed on the N210 component, $F(1, 12) = 8.13$, $P < 0.05$, which further interacted with electrode site, $F(1.22, 14.69) = 4.38$, $P < 0.05$. Subsidiary analyses revealed that at midline and left hemisphere sites, Black faces elicited a larger negative component than did White faces: $F(1, 12) = 9.54$, $P < 0.01$, and $F(1, 12) = 10.80$, $P < 0.01$, respectively. Lastly, a main effect of race was observed on the mean amplitude of the P400 component, $F(1, 12) = 8.58$, $P < 0.05$, whereby White faces elicited a larger positive peak than did Black faces.

Contact correlations with neural components. For each ERP component modulated by race (N170, N210 and P400), race effects were computed by subtracting the mean amplitude of potentials evoked by White faces from those
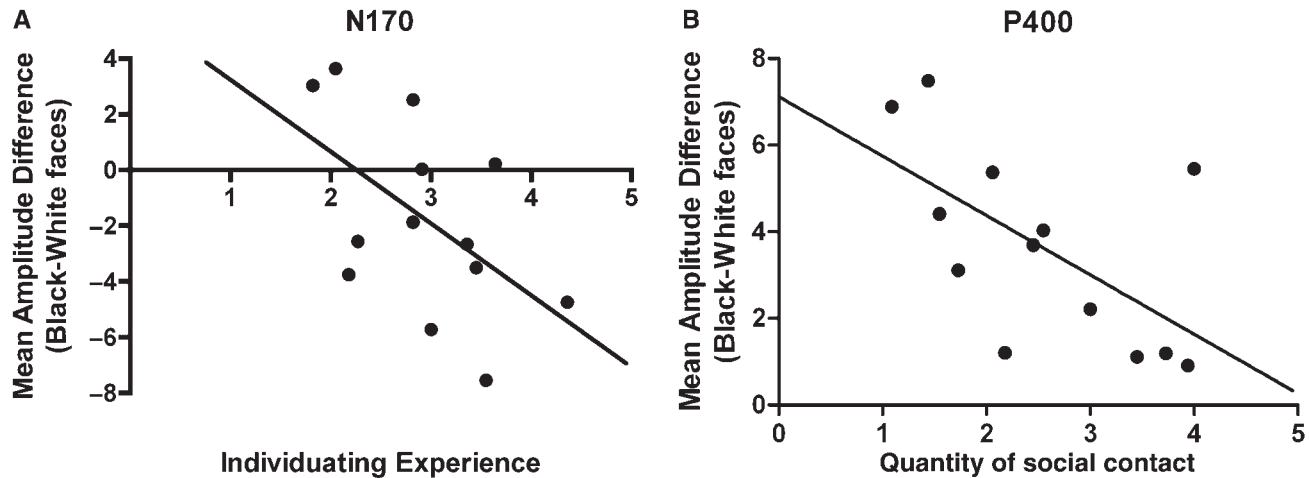
A   **N170**

B   **P400**

Fig. 5 Correlation plots demonstrate the significant relationship between (**A**) individuating experience and N170 mean amplitude differences between Black and White faces and (**B**) social contact and P400 mean amplitude differences between Black and White faces.

evoked by Black faces (Correll *et al.*, 2005). To maximize sensitivity, race effects were computed at the electrode at which the effect was maximal (P8 for N170, CPZ for N210 and FZ for P400). These scores were entered into a bivariate correlation with the self-report measures of *social contact* and *individuating experience* to determine whether greater other-race exposure was linked to a smaller difference between own-race and other-race face processing. Race effects for the N170 were found to correlate negatively with individuating experience, $r = -0.55$, $P = 0.05$, whereby participants who reported more other-race individuating experience demonstrated a smaller difference in N170 mean amplitudes to own-race *vs* other-race faces. Moreover, contrast scores for the mean amplitude of the P400 were found to correlate negatively with social contact, $r = -0.61$, $P < 0.05$; participants who reported more social contact with other-race individuals demonstrated a smaller difference in P400 mean amplitudes elicited by own-race *vs* other-race faces. Correlation plots confirmed that no outliers were driving this effect (Figure 5A and B). These correlations were further substantiated by analyses of covariance (ANCOVA), which showed that by controlling for the contact correlates, the previously observed race-of-face effects were nullified (for the N170, controlling for individuating contact, $F(1, 11) = 2.42$, $P = 0.15$; for the P400, controlling for social contact, $F(1, 11) = 2.46$, $P = 0.15$).

DISCUSSION

The current experiment adopted a multi-tier approach in order to isolate face-related processing, to test its modulation by the race of the stimulus, and to test for the influence of other-race experience measures upon race-related effects. Experimental results demonstrated that this approach was successful. By comparing both the morphologies and the topographies of brain activity related to face *vs* blur stimuli, three face-specific components were isolated. The first face-related component identified by morphological and

topographical analyses was the well-known N170 (Bentin *et al.*, 1996). Second, morphological and topographical analyses revealed a late face-related component, the P400, peaking between 360 and 420 ms over frontocentral sites. The P400 is similar to reports of late face-related potentials recorded intracranially (Allison *et al.*, 1999; Puce *et al.*, 1999), but has not been commonly reported in scalp ERP studies. Puce and colleagues (1999) recorded a P350 component intracranially from the anterior temporal cortex, and found it was specific to faces *vs* objects and subject to top-down influences. The P400 recorded in the current study may reflect the same stage of face-related processing as the intracranial P350. A third component was isolated by the morphological analysis but not by the topographical analysis: the N210. The N210 was a brief intermediary centro-parietal component peaking between 200 and 220 ms. The brevity and spatially focal nature of this effect, as well as its overlap with the larger P2 component around the same time, may have made the topographical analysis less sensitive to this component.

The experimental manipulation of face orientation validated the identification of the three aforementioned face-related components. The face-inversion latency effects observed on the N170 were in line with previous ERP findings (Bentin *et al.*, 1996; Eimer, 2000; Rossion *et al.*, 2000, 2003; Taylor *et al.*, 2001) and may reflect a delaying or lengthening of the neural processing linked to structural encoding. The N210 was smaller and delayed to inverted *vs* upright faces. By the P400 stage of face processing, face orientation no longer elicited a latency shift, but the component was substantially diminished by inversion. The non-face-related visual P120 was also affected by face inversion, in line with previous research (Itier and Taylor, 2004a, b), demonstrating that inverted faces are sufficiently different in face-unrelated perceptual attributes to modulate early stages of general perceptual analysis. This particular finding raises a note of caution when attributing changes in

ERPs to face-related processing without careful controls in place (e.g. faces *vs* blurs, faces *vs* objects).

Equipped with distinct markers of face-related processing from the stage of structural encoding to cognitive evaluation, it was possible to assess the effect of race on face-related processing. Race affected all three identified stages of face-related processing.

The mean amplitude of the first face-related component, the N170, was modulated by race. This effect was not related to stimulus color as demonstrated by a follow-up analysis comparing white *vs* black control blur stimuli. Subsequent correlations between mean amplitudes of White *vs* Black faces and other-race individuating experience showed that participants with greater one-on-one contact with the other-race showed less of a difference in N170 mean amplitudes during the structural encoding of White *vs* Black faces. These findings are the first of their kind, and suggest that other-race experience plays an integral role in the way in which one encodes own-race *vs* other-race faces from early perceptual stages of processing.

To date, the literature has been inconsistent about modulation of the N170 by race. In fact, experimentally reported race modulations of the N170 appear to be highly task-dependent. As seen in the studies by Ito and colleagues, own-race faces elicited larger N170s than did other-race faces. These race modulations of the N170 were, however, only observed when participants completed social-categorization tasks. In contrast, Caldara and colleagues (2003) and James and colleagues (2001) employed recognition memory tasks and found no modulation of the N170 component by race. The functional significance of the direction of modulation of the N170 by race-of-face cannot be inferred from the present data. We propose that the enhancement of the N170 elicited by other-race faces reflects the increased demands placed upon extracting the configural features of the face during structural encoding. Neural processing at this stage may be enhanced due to task difficulty, and may involve additional perceptual functions. Furthermore, we show that the individual differences relating to experience with other-race individuals play an important mediating role.

Similarly, the N210 mean amplitude was affected by race, although no correlations between this effect and other-race experience were noted. Because this component has not previously been isolated, effects of race on this component have not been discussed in the literature. Nevertheless, the current findings demonstrate the continued effects of race over consecutive stages of face processing.

The late stage of face processing, the P400, was also affected by race. Specifically, the mean amplitude of the P400 was larger for own-race than other-race faces. The increased amplitude of the P400 to own-race faces may reflect the cognitive evaluation of race and category-related information. This race effect was also correlated with other-race social contact, demonstrating that greater other-race contact facilitates similar own-race *vs* other-race face processing.

The evidence presented in this article highlights not only differential own-race *vs* other-race face processing from early structural encoding through later stages of face processing, but also that these effects are dependent upon social experiential factors. Such findings demonstrate the malleability of our internal neural and cognitive functioning by external social influences. As such, race perception and racial bias in today's society may be culturally influenced (i.e. linked to social norms and the ethnic make-up of the given society). Both social and environmental influences may impact the way in which individuals in a given society process race information. The results from the present experiment provide evidence suggesting that neural activation to race-related information may be heavily shaped by social learning, and that personal experience with members of these groups can modulate race-of-face processing. The present findings linking a neural own-race effect with measures of other-race experience are in line with the contact hypothesis (Allport, 1954; Brown and Hewstone, 2005). Greater personal experience with members of other racial groups may enable individuals to learn and subsequently generalize the new physiognomic cues of individual other-race faces to the perceptions of all faces of that racial group.

In sum, the present experiment demonstrates that effects of race occur relatively early, during perceptual analysis of faces (N170), and percolate through multiple stages of face processing. Differences in own-race *vs* other-race face processing at the neural level substantiate previous behavioral research on the own-race effect, while results from correlational analyses reveal that race effects may be related to the degree of experience an individual has with different races. Indeed, individuals with more other-race experience show more similarity in the processing of own and other-race faces, whilst those with less experience show greater disparity and disruption in the processing of other- *vs* own-race faces. Ultimately, these findings have important implications for future research exploring the influence of social factors on neural stimulus processing.

REFERENCES

Adolphs, R. (2001). The neurobiology of social cognition. *Current Opinion in Neurobiology*, 11, 231–9.

AEEGS.(1991). American Electroencephalographic Society guidelines for standard electrode position nomenclature. *Journal of Clinical Neurophysiology*, 8, 200–2.

Allison, T., Ginter, H., McCarthy, G., Nobre, A.C., Puce, A., Luby, M., et al. (1994a). Face recognition in the human extrastriate cortex. *Journal of Neurophysiology*, 71(2), 821–5.

Allison, T., McCarthy, G., Nobre, A., Puce, A., Belger, A. (1994b). Human extrastriate visual cortex and the perception of faces, words, numbers, and colors. *Cerebral Cortex*, 5, 544–54.

Allison, T., Puce, A., McCarthy, G. (2000). Social perception from visual cues: role of the SRS region. *Trends in Cognitive Science*, 4, 267–78.

Allison, T., Puce, A., Spencer, D.D., McCarthy, G. (1999). Electrophysiological studies of human face perception. I: potentials

generated in occipitotemporal cortex by face and non-face stimuli. *Cerebral Cortex*, *9I*, 415–30.

Allport, G.W. (1954). *The Nature of Prejudice*. Reading, MA: Addison-Wesley.

Bentin, S., Allison, T., Puce, A., Perez, E., McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience*, *8I*, 551–65.

Bodamer, J. (1947). Die Prosop-Agnosie. *Archiv fur Psychiatrie und Nervenkrankheiten*, *179*, 6–53.

Brandeis, D., Naylor, H., Halliday, R., Callaway, E., Yano, L. (1992). Scopolamine effects on visual information processing, attention and event-related potential map latencies. *Psychophysiology*, *29*, 315–36.

Brown, R., Hewstone, M. (2005). An integrative theory of inter-group contact. In: Zanna, M., editor. *Advances in Experimental Social Psychology*, San Diego, CA: Academic Press, Vol. 37, pp. 255–343.

Caldara, R., Rossion, B., Bovet, P., Hauert, C.A. (2004). Event-related potentials and timecourse of the 'other-race' face classification advantage. *NeuroReport*, *15*, 905–10.

Caldara, R., Thut, G., Servoir, P., Michel, C., Bovet, P., Renault, B. (2003). Face versus non-face object perception and the ''other-race'' effect: a spatio-temporal ERP study. *Clinical Neurophysiology*, *114*, 515–28.

Carroo, A.W. (1987). Recognition of faces as a function of race, attitudes, and reported cross-racial friendships. *Perceptual and Motor Skills*, *64*, 319–25.

Correll, J., Urland, G.R., Ito, T.A. (2005). Event-related potentials and the decision to shoot: The role of threat perception and cognitive control. *Journal of Experimental Social Psychology*. *42*, 120–128.

Cunningham, W.A., Johnson, M.K., Gatenby, J.C., Gore, J.C., Banaji, M.R. (2003). Neural components of social evaluation. *Journal of Personality and Social Psychology*, *85*, 639–49.

Cunningham, W.A., Johnson, M.K., Raye, C.L., Gatenby, J.C., Gore, J.C., Banaji, M.R. (2004). Separable neural components in the processing of black and white faces. *Psychological Science*, *15*, 806–13.

Damasio, A.R., Damasio, H., Van Hoesen, G.W. (1982). Prosopagnosia: anatomical basis and neurobehavioural mechanism. *Neurology*, *32*, 331–41.

Eberhardt, J.L. (2005). Imaging race. *American Psychologist*, *60*, 181–90.

Eimer, M. (1998). Does the face-specific N170 component reflect the activity of a specialized eye detector? *NeuroReport*, *9*, 2945–8.

Eimer, M. (2000). Event-related brain potentials distinguish processing stages involved in face perception and recognition. *Clinical Neurophysiology*, *111*, 694–705.

Fletcher, P.C., Happe, F., Frith, U., et al. (1995). Other minds in the brain: a functional imaging study of 'theory of mind' in story comprehension. *Cognition*, *57*, 109–28.

Frith, C.D., Frith, U. (1999). Interacting minds-a biological basis. *Science*, *286*, 1692–5.

Gallagher, H.L., Happe, F., Brunswick, N., Fletcher, P.C., Frith, U., Frith, C.D. (2000). Reading the mind in cartoons and stories: an FMRI study of 'theory of mind' in verbal and nonverbal tasks. *Neuropsychologia*, *38*, 11–21.

George, N., Evans, J., Fiori, N., Davidoff, J., Renault, B. (1996). Brain events related to normal and moderately scrambled faces. *Cognitive Brain Research*, *4*, 65–76.

Golarai, G., Ghahremani, D., Eberhardt, J.L., Grill-Spector, K.J., Gabrieli, J.D. (2004). Representations of parts and canonical face configuration in the amygdala, superior temporal sulcus (STS) and the fusiform ''face area''. Paper presented at the Fourth Annual Meeting of the Vision Science Society, Sarasota, FL.

Golby, A.J., Gabrieli, J.D.E., Chiao, J.Y., Eberhardt, J.L. (2001). Differential fusiform responses to same- and other-race faces. *Nature Neuroscience*, *4*, 845–50.

Hart, A.J., Whalen, P.J., Shin, L.M., McInerney, S.C., Fischer, H., Rauch, S.L. (2000). Differential response in the human amygdala to racial outgroup vs. ingroup face stimuli. *NeuroReport*, *11*, 2351–5.

Haxby, J.V., Hoffman, E.A., Gobbini, M.I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Science*, *4*, 223–33.

Itier, R.J., Taylor, M.J. (2004a). Effects of repetition and configural changes on the development of face recognition processes. *Developmental Science*, *7*, 469–87.

Itier, R.J., Taylor, M.J. (2004b). Face recognition memory and configural processing: a developmental ERP study using upright, inverted and contrast-reversed faces. *Journal of Cognitive Neuroscience*, *16*, 1–15.

Ito, T.A., Thompson, E., Cacioppo, J.T. (2004). Tracking the timecourse of social perception: the effects of racial cues on event-related brain potentials. *Personality and Social Psychology Bulletin*, *30*, 1267–80.

Ito, T.A., Urland, G.R. (2003). Race and gender on the brain: electro-cortical measures of attention to race and gender of multi-ply categorizable individuals. *Journal of Personality and Social Psychology*, *85*, 616–26.

Ito, T.A., Urland, G.R. (2005). The influence of processing objectives on the perception of faces: an ERP study of race and gender perception. *Cognitive, Affective, and Behavioural Neuroscience*, *5*, 21–36.

James, M.S., Johnstone, S.J., Hayward, W.G. (2001). Event-related potentials, configural encoding and feature-based encoding in face recognition. *Journal of Psychophysiology*, *15*, 275–85.

Jeffreys, D.A. (1989). A face-responsive potential recorded from the human scalp. *Experimental Brain Research*, *78*, 193–202.

Jemel, B., George, N., Chaby, L., Fiori, N., Renault, B. (1999). Differential processing of part-to-whole and part-to-part face priming: an ERP study. *NeuroReport*, *10*, 1069–75.

Jennings, J.R., Wood, C.C. (1976). The epsilon-adjusted procedure for repeatedmeasures analyses of variance. *Psychophysiology*, *13*, 277–8.

Joyce, C.A., Rossion, B. (2005). The face-sensitive N170 and VPP components manifest the same brain processes: the effect of reference electrode site. *Clinical Neurophysiology*, *116*, 2613–31.

Kanwisher, N., McDermott, J., Chun, M. (1997). The fusiform face area: a module in human extrastriate cortex specialized for the perception of faces. *Journal of Neuroscience*, *17*, 4302–11.

Khateb, A., Annoni, J.M., Landis, T., et al. (1999). Spatio-temporal analysis of electric brain activity during semantic and phonological word processing. *Internal Journal of Psychophysiology*, *32*, 215–31.

Lehman, D., Skrandies, W. (1980). Reference-free identification of components of checkerboard-evoked multichannel potential fields. *Clinical Neurophysiology*, *48*, 609–21.

Levin, D.T. (2000). Race as a visual feature: using visual search and perceptual discrimination tasks to understand face categories and the cross race recognition deficit. *Journal of Experimental Psychology: General*, *129*, 559–74.

Lieberman, M.D., Hariri, A., Jarcho, J.M., Eisenberger, N.I., Bookheimer, S.Y. (2005). An fMRI investigation of race-related amygdala activity in African-American and Caucasian-American individuals. *Nature Neuroscience*, *8*, 720–2.

McCarthy, G., Puce, A., Belger, A., Allison, T. (1999). Electrophysiological studies of human face perception. II: response properties of face-specific potentials generated in occipitotemporal cortex. *Cerebral Cortex*, *9*, 431–44.

Michel, C.M., Henggeler, B., Lehmann, D. (1992). 42-Channel potential map series to visual contrast and stereo stimuli: perceptual and cognitive event-related segments. *International Journal of Psychophysiology*, *12*, 133–45.

Nobre, A.C., McCarthy, G. (1994). Language-related ERPs: scalp distribution and modulation by word-type and semantic priming. *Journal of Cognitive Neuroscience*, *6*, 233–55.

Oldfield, R.C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia*, *9*, 97–113.

O'Toole, A.J., Deffenbacher, K., Abdi, H., Bartlett, J.C. (1991). Simulating the other race effect. *Connection Science*, *3*, 163–78.

Paolini, S., Hewstone, M., Cairns, E. (2007). Direct and indirect friendship effects: testing the moderating role of the affective-cognitive bases of prejudice. *Personality and Social Psychology Bulletin*, *33*(10), 1406–1420.

Paolini, S., Hewstone, M., Cairns, E., Voci, A. (2004). Effects of direct and indirect cross-group friendships on judgments of Catholics and Protestants in Northern Ireland: the mediating role of an anxiety-reduction mechanism. *Personality and Social Psychology Bulletin*, *30*, 770–86.

Pasqual-Marqui, R.D., Michel, C.M., Lehman, D. (1995). Segmentation of brain electrical activity into microstates: model estimation and validation. *IEEE Transactions on Biomedical Engineering*, *42*, 658–65.

Pegna, A.J., Khateb, A., Spinelli, L., Seeck, M., Landis, T., Michel, C.M. (1997). Unravelling the cerebral dynamics of mental imagery. *Human Brain Mapping*, *5*, 410–421.

Pelphrey, K.A., Singerman, J.D., Allison, T., McCarthy, G. (2003). Brain activation evoked by perception of gaze shifts: the influence of context. *Neuropsychologia*, *41*, 156–70.

Pettigrew, T.F., Tropp, L.R. (2006). A meta-analytic test of intergroup contact theory. *Journal of Personality and Social Psychology*, *90*, 751–83.

Phelps, E.A., O'Connor, K.J., Cunningham, W.A., et al. (2000). Performance on indirect measures of race evaluation predicts amygdala activity. *Journal of Cognitive Neuroscience*, *12*, 1–10.

Puce, A., Allison, T., Asgari, M., Gore, J.C., McCarthy, G. (1996). Differential sensitivity of human visual cortex to faces, letter strings, and textures: a functional magnetic resonance imaging study. *Journal of Neuroscience*, *16*, 5205–15.

Puce, A., Allison, T., Bentin, S., Gore, J.C., McCarthy, G. (1998). Temporal cortex activation in humans viewing eye and mouth movements. *Journal of Neuroscience*, *18*, 2188–99.

Puce, A., Allison, T., Gore, J.C., McCarthy, G. (1995). Face-sensitive regions in human extrastriate cortex studied by functional MRI. *Journal of Neurophysiology*, *74*, 1192–9.

Puce, A., Allison, T., McCarthy, G. (1999). Electrophysiological studies of human face perception III: effects of top-down processing on face-specific potentials. *Cerebral Cortex*, *9*, 445–58.

Puce, A., Syngeniotis, A., Thompson, J.C., Abott, D.F., Wheaton, K.J., Castiello, U. (2003). The human temporal lobe integrates facial form and motion: evidence from FMRI and ERP studies. *Neuroimage*, *19*, 861–9.

Richeson, J.A., Baird, A.A., Gordon, H.L., et al. (2003). An fMRI investigation of the impact of interracial contact on executive function. *Nature Neuroscience*, *6*, 1323–8.

Rossion, B., Delvenne, J., Debatisse, D., et al. (1999). Spatio-temporal brain localization of the face inversion effect: an event-related potentials study. *Biological Psychology*, *50*, 173–89.

Rossion, B., Gauthier, I., Tarr, M.J., et al. (2000). The N170 occipito-temporal component is enhanced and delayed to inverted faces but not to inverted objects: an electrophyiological account of face-specific processes in the human brain. *NeuroReport*, *11*, 1–6.

Rossion, B., Joyce, C., Cottrell, G.W., Tarr, M.J. (2003). Early lateralization and orientation tuning for face, word and object processing in the visual cortex. *Neuroimage*, *20*, 1609–24.

Sergent, J., Ohta, S., MacDonald, B. (1992). Functional neuroanatomy of face and object processing. A positron emission tomography study. *Brain*, *115*, 15–36.

Slone, A.E., Brigham, J.C., Meissner, C.A. (2000). Social and cognitive factors affecting the own-race bias in whites. *Basic and Applied Social Psychology*, *22*(2), 71–84.

Sporer, L.S. (2001). Recognizing faces of other ethnic groups. *Psychology, Public Policy and Law*, *7*, 36–97.

Taylor, M.J., Edmonds, G.E., McCarthy, G., Allison, T. (2001). Eyes first! Eye processing develops before face processing in children. *NeuroReport*, *12*, 1671–6.

Turner, R., Hewstone, M., Voci, A. (2007). Reducing explicit and implicit outgroup prejudice via direct and extended contact: the mediating role of self-disclosure and intergroup anxiety. *Journal of Personality and Social Psychology*, *93*, 369–388.

Voci, A., Hewstone, M. (2003). Intergroup contact and prejudice toward immigrants in Italy: the mediational role of anxiety and the moderational role of group salience. *Group Processes and Intergroup Relations*, *6*, 37–54.

Walker, P.M., Hewstone, M. (in press). The influence of social factors and implicit racial bias on a generalized own-race effect. *Applied Cognitive Psychology*.

Walker, P.M., Hewstone, M. (2006a). A perceptual discrimination investigation of the own-race effect and intergroup experience. *Applied Cognitive Psychology*, *20*, 41–75.

Walker, P.M., Tanaka, J.W. (2003). A perceptual encoding advantage for own- versus other-race faces. *Perception*, *32*, 1117–25.

Wheeler, M.E., Fiske, S.T. (2005). Controlling racial prejudice and stereotyping: social cognitive goals affect amygdala and stereotype activation. *Psychological Science*, *16*, 56–63.

Winston, J.S., Strange, B.A., O'Doherty, J., Dolan, R.J. (2002). Automatic and intentional brain responses during evaluation of trustworthiness of faces. *Nature Neuroscience*, *5*, 277–83.

Wright, D.B., Boyd, C.E., Tredoux, C.G. (2003). Inter-racial contact and the own-race bias for face recognition in South Africa and England. *Applied Cognitive Psychology*, *17*, 365–73.

Wright, D.B., Sladden, B. (2003). An own gender bias and the importance of hair in face recognition. *Acta Psychologia*, *114*, 101–14.